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Original Article

Post-activation performance enhancement: Acute effected after activation in kayak sprint

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Abstract
Preconditioning strategies before a competition are extremely important, especially in sports that use speed and power as key performance benefits. Kayak sprint is a sport that requires the necessary use of power and speed as the key performance aspects, which may benefit from the strategies in this work. This study aimed to compare the acute effects and differences in post-activation performance enhancement (PAPE) on physiological and performance in kayak paddle. Twelve men kayak paddle sub-elite participated in this research through a randomized crossover trial. All participants performed three different protocols consisting of the Resistance activation protocol (2x4x80%1RM x Bench press and Bench row), Maximum sprint paddle (2x20 sec x rest interval 2 min), and the control group followed by a 3-minute test. Maximum power, power average, stroke per minute, total distance, percentage of heart rate and blood lactate concentration each period were measured. For the main effect of MANOVA, it was found that only maximum power performance in resistance activation and maximum paddle method was higher than the control group; no difference was observed in other variables. There was an interaction effect (Intervention x Period) of blood lactate found, in which Resistance activation and Maximum sprint paddle were higher than the control group after the intervention period. Before the 3-minute test period, the Maximum sprint paddle was different from the other group, and resistance activation was higher than the control group 6 minutes after the test. Blood lactate showed significance in all periods except after intervention and before the 3-minute test period in the resistance activation and the Maximum sprint paddle group. Activation by using the resistance or maximum speed paddle method could improve maximum power temporarily. Blood lactate increased after intervention, persisted after the intervention, and continued for several minutes. The application of this method should be taken into consideration regarding the fatigue that occurs and potentially affects other performance indicators.
Key Words: Preconditioning, Rate of force development, Maximum power, Maximum voluntary contraction, Warm up strategies.

Introduction

Post-Activation Performance Enhancement (PAPE) is a strategy to activate muscles for improving physical performance. The physiological mechanism for PAPE involves increased temperature in physical activity, fluid muscle fiber, and muscle activation (Blazevich & Babault, 2019; Boullosa, 2021). The mechanism for PAPE may include involvement in the Phosphorylation myosin regulatory light chain (MRLC) continuously from Post Activation Potential (PAP) or no involvement at all (Zimmermann et al., 2020). Primarily, PAPE is used during a warm-up before training for competitive sports or physical performance testing (Cuenca-Fernández et al., 2020; McGowan et al., 2015). This method can improve the rate of force development (RFD), which is a maximum voluntary contraction (MVC) performance enhancement after several minutes of activity (Blazevich & Babault, 2019; Prieske et al., 2020). PAPE can improve physical performance in terms of strength, speed, and power (Bielitzki et al., 2021; Brink et al., 2021), which is a benefit for improving athlete performance (Boullosa, 2021; Živanović, 2022). Strategies for preconditioning may be used as a resistance activity (Krzysztofik et al., 2021; Smith et al., 2014). Maximum effort is used to keep the muscles working at high speed and in a shorter time (Brink et al., 2021). These activities are suitable for stimulation during the warm-up period for performance enhancement (Borba et al., 2017).

The workload for activation in the PAPE mechanism involves high intensity and low volume in order to avoid fatigue, which is a factor for inhibiting performance. A suitable load will help improve performance for athletes (Ribeiro et al., 2021). From a review of the literature on a meta-analysis of PAPE, experts suggest the load for muscle activation should include more than 70% 1RM resistance training, with a volume of fewer than 6 repetitions and 2-3 sets (Boullosa, 2021). In addition, the recovery time after activation should be between 5-15

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minutes (Blazevich & Babault, 2019; Boullosa, 2021). Some experts explain that peak performance for athletes depends on experience (Seitz & Haff, 2016). Those with a lot of experience will benefit more from the PAPE mechanism. Associated factors such as activity intensity, recovery time, and readiness for physical and sports have been involved in improving performance (Boullosa, 2021). The application of the PAPE theory in sports has become increasingly appealing in recent years in sports where speed and power are key performance factors (Bielitzki et al., 2021; Brink et al., 2021). Kayak sprint is one of the sports that require speed and power performance for a paddle as well as for anaerobic energy consumption as a key metabolic activity (Michael et al., 2008). The PAPE concept, therefore, is interesting to use for warm-up strategies in this sport. Before training or competition, a warm-up process is important and will allow athletes to have high performance. Warm-up strategies that are appropriate can help to prepare for physical activity and increase performance ability for paddling (Akca & Aras, 2018). Any preconditioning protocol must be appropriate and consistent with a kayak paddle. Kayak sprint characteristics will emphasize the upper body strength for paddling (Michael et al., 2008; Pickett et al., 2018). Stimulation during warm-up should be specific to the Kayak sprint paddle. In previous studies, McKean and Burkett (2014) studied the upper body muscle group for the kayak sprint, which should be trained using dynamic muscle contractions such as pull and press exercises that are consistent with the kayak sprint. Dynamic resistance training will improve physical performance for athletes as well (Smith et al., 2014; Živanović, 2022). The present study describes the mechanisms that occur after activation using different methods for the improvement of physical performance (Boullosa, 2021; Brink et al., 2021). However, there is no mention of cyclic sports skills that last more than 2-3 minutes after preconditioning related to PAPE. Therefore, this study focuses on experiments and practical applications in training or competitive kayak sprint sport. Strategies such as resistance exercise activities during a warm-up period are used by activating specific muscles for the kayak sprint or the maximum effort paddle (all-out) by kayak sprint paddling in a short time. A kayak ergometer may be an option for improving physical ability such as speed and power for muscles. The PAPE mechanism may improve performance in the short continuous paddle and can be practiced during the maximum sprint training period which is applied to competition or testing.

Material & methods

The experimental studies used a crossover design and Latin square design for the trial plan assigns intervention. Compared performance and variable are related to kayak paddle after the difference of PAPE intervention. This study was approved for ethical human research by the Committee on Ethics in Human Research from Strategic Wisdom and Research Institute, Srinakharinwirot University (SWUEC-G-210/2565) which conduct in the Declaration of Helsinki.

Participants

Twelve male kayak paddle sprinters, Thailand national team who are into kayak sprint international competition. (Age 22.4 ± 4.6 years, Body mass 75.5 ± 4.4 kg., Height 176±6.1 cm.) (Table 1). Participants calculate by an effect size 0.74. Inclusion criteria, kayak paddle sprinters who attend the studies will be required to have experience of at least 3 years, participated in international competitions, and have no joint or muscle injury problems. The experiments will alternate according to a crossover design and trial plan Latin square design. The subject will be divided into three interventions; resistance activation protocol (RAP), Maximum sprint paddle (MSP) and Control Group (CON).

Physical characteristics testing

All participants will have an experiment at the sports science laboratory every trial, in which every experiment, there is temperature control of 22-25 °C every time. Before the test, the subject understands prohibitions such as not having moderate to high activities including resistance exercise for 48 hours and avoiding drinks containing caffeine for 24 hours. First time in the laboratory they will be measured physical characteristics, body mass, height, and one repetition maximum (1RM) of bench press and bench row by using protocol (Haff & Triplett, 2016), after the test, they will rest at least 48 hr. then onto next test. The second time, the VO2Max test by using increment step test protocol, the subject wears a portable gas analyzer (PNOE, ENDO Medical, Palo Alto, CA, USA) on a kayak ergometer (Kayak Ergometer, WEBA Sport und med. Artikel GmbH, Liesneckgasse, Wien, Austria) and start at 100 watts then 30 watts increase every 2-minute, and by the end of the test depends on 2 from 4 criteria; VO2 plateau <150 ml/min, respiratory exchange ratio (RER) equal to 1.15 or more, heart rate maximum (220-age) and exhaustion cannot continue testing. Total time of test between 8-12 minutes. After the end of the test, the subject rest at least 72 hours before the next step of the experiment.

Table 1 Descriptive characteristics of participants

Characteristics		**Mean ± SD**
Age (years)		25.40 ± 4.60
Body mass (kg.)		75.50 ± 4.43
Height (cm.)		176 ± 6.15
VO2Max (ml/kg/min)		52.74 ± 5.30
One repetition maximum (kg)	Bench Press	111.25 ± 13.29
	Bench Row	109.70 ± 8.87

Intervention

Participants will have a standardized warm-up on a kayak ergometer at 50-60% of the maximum heart rate (Polar H10, Kempele, Finland) for 5-10 minutes then static combine with dynamic stretching for 5 minutes, then rest for 5 minutes followed by an activate PAPE Intervention consisted of; (A) Resistance Activated Protocol; bench press and bench row exercises performed load 80% 1RM for 2-3 sets and recovery between sets for 1-2 minutes adapted from previous suggesting literature (Boullosa, 2021; Seitz & Haff, 2016) and applied for a kayak paddle, (B) Maximum paddle effort; performing maximum effort paddle on a kayak ergometer all-out 10 seconds and 2-minute rest interval for 2 sets (Harat et al., 2020), or (C) Control group, a warm-up protocol by themselves not over 10 minutes. After finishing, performing PAPE intervention, which will have a recovery time of 7 to 10 minutes according to the PAPE mechanism (Boullosa, 2021) then performance test.

Test protocol

Maximum paddle effort 3-minute test all-out (3MT) is a protocol for indicating critical power and anaerobic work capacity (Bergstrom et al., 2012). The recent concept of critical power should not be separated between anaerobic and anaerobic, because aerobic systems and anaerobic systems work by combining together (Poole et al., 2016). When paddle maximal effort is 3 minutes, muscle power will decrease till exhausted. These studies adopt a 3-minute test from previous studies by using a maximum effort 3-minute on a kayak ergometer. The researcher asks for collaboration subjects to fully paddle for a maximum of 3 minutes of testing. In order for the effectiveness of the intervention to be shown the highest performance, during paddling on a kayak ergometer participants cannot see numeric on the monitor, and the researcher will motivate and encourage them throughout the test.

Data collection and analysis

Maximum power (MxP), power average (Pavr), stroke per minute (SPM), and total distance (Dist) were controlled and recorded by computer software (Weba Science). Percentage of heart rate (PHR) during 3-minute test all-out was recorded and controlled throughout the paddle (Polar H10, Kempele, Finland). Blood lactate concentration ([La-]b) (Lactate Plus Meter, Nova Biomedical, MA, USA) was measured in capillary samples obtained from the earlobe before standardized warm-up, after the activated PAPE intervention, before a 3-minute test, and after a 3-minute test for 6 minutes period. Participants who have finished the 3-minute test by using Resistance activation Protocol, the Maximum sprint paddle or control group, will have to rest for 72 hrs. for another experiment crossover intervention again.

Statistical analysis

The statistical analysis represents as mean ± SD by using SPSS version 26, IBM, Chicago, Illinois, United States of America. Normality of distribution data using Shapiro-Wilk test. One-way multivariate analysis of variance (One-way MANOVA) for maximum power, average power, stroke per minute, and total distance and percentage of heart rate variable. Blood lactate using Two-way ANOVA with a repeated measure to compare the interaction between intervention x period. The Bonferroni test determined which measures differed significantly. All statistical level of significance was set at $P \leq .05$.

Results

All result performance parameter showed in table 2. The main effect of MANOVA is different between groups for maximum power (P = .013); Resistance activation protocol (274.90± 31.99) and Maximum sprint paddle (271.90 ± 26.15) which increase significantly higher than control (243.27 ± 15.90) (Figure 1). There was no significant difference between the group in power average, stroke per minute, and total distance variable (P = .526, P = .159, and P = .161 respectively) and no difference for percentage of heart rate (P =.217); Resistance activation protocol; 91.00 ± 3.43, Maximum sprint paddle; 92.41 ± 2.31 and control group; 90.25 ± 3.16.

Table 2 Mean and difference of performance variable after 3-minute test all-out on Kayak ergometer

Intervention	MxP	Sig.	Pavr	Sig.	SPM	Sig.	Dist	Sig.	One-way MANOA
	Mean ± SD		**Mean ± SD**		**Mean ± SD**		**Mean ± SD**		
CON	243.27 ± 15.90		205.27 ± 14.6		102.36 ± 5.55		637.27 ± 18.48		
MSP	271.90* ± 26.15	.013#	207.6 ± 14.65	.526	105.5 ± 2.75	.159	644 ± 10.74	.161	.020+
RAP	274.90* ± 31.99		199.45 ± 20.5		102.09 ± 4.13		630 ± 17.88		

Note. **Significant difference when compared with CON (P < .05)* #*Significant difference between group (P < .05),* +*Significant by multivariate analysis of variance (MANOVA) (P < .05), CON; Control group, MSP; Maximum sprint paddle and RAP; Resistance activation protocol, MxP; Maximum power, Pavr; power average, SPM; stroke per minute and Dist; total distance.*

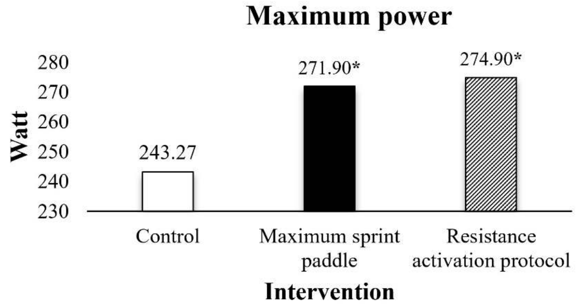

Figure 1 Maximum power per stroke each intervention
Note. **Significant difference when compared with CON (P ≤ .05).*

Blood lactate concentration had an interaction effect between intervention x period significantly (*P* ≤ .001), the post hoc test shows the result after the intervention period found that Resistance activation protocol (3.60 ± 1.03) and Maximum sprint paddle (4.23 ± 1.33) was higher than the control (2.12 ± 0.46) significantly (*P* = .003 and *P* = .001 respectively) as well as before 3-minute test period, Maximum sprint paddle (4.27 ± 1.31) higher than Resistance activation protocol (3.05 ± 0.76, *P* =.007) same as control group (1.68 ± 0.40, *P* = .001) and Resistance activation protocol higher than control group *P* = .002. After test 6-minute, Resistance activation protocol higher than control group (12.33 ± 2.11 vs 10.62 ± 0.78) (Figure 2).

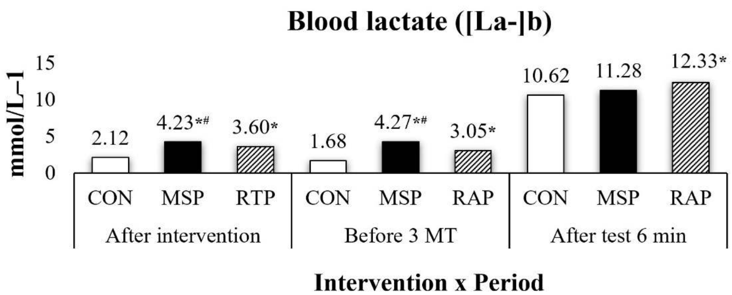

Figure 2 Blood lactate interaction between period x intervention
Note. **Significant difference when compared with CON (P < .05) #Significant difference when compared with RAP (P < .05) CON; Control group, MPE; Maximum paddle effort and RAP; Resistance activation protocol.*

Discussion

The mechanism for post-activation performance enhancement can improve power and speed performance (Borba et al., 2017; Brink et al., 2021; Krzysztofik et al., 2021). The physiological mechanism of PAPE has worked within muscle fibers after being stimulated for several minutes (7-15 min) (Blazevich & Babault, 2019; Seitz & Haff, 2016). After stimulation by external loads such as maximum exertion of effort, short time, or resistance load will cause maximum voluntary contraction, which is a mechanism from the increased neural drive level that affects force, power, and the rate of force development (RFD). After being activated by using the fast contraction method for muscles, the recruitment of the motor units is increased (Tillin & Bishop, 2009). The fast contraction of muscles causes readiness to perform activities related to improved muscle power. The strategies used for activating muscles by resistance will affect muscle stiffness after exertion (Dankel & Razzano, 2020). For this reason, intramuscular stiffness caused by resistance activities or the stimulation of muscles can increase force and power (Edman & Josephson, 2007). Therefore, the stiffness mechanism within the muscles as above could affect the improvement of power and muscle performance in a paddle after a resistance intervention. In addition, the muscle stiffness mechanism may rise from the fluid mechanism (blood or water) after activation. The mechanism may stimulate an increase in intramuscular stiffness (Eng & Roberts, 2018)within the muscle fibers, meaning blood or water will increase flow and infiltrate more into the muscle fibers.

A meta-analysis of previous studies has found that an increase in temperature after warm-up or stimulation is another factor that causes maximum voluntary contraction after several minutes (Blazevich & Babault, 2019). After a warm-up or activity that increases the load on the muscles, there will be an increase in temperature corresponding to the flow of water within the body. Intramuscular fluid flow may relate to the effect of an increase in temperature in the muscle (Blazevich & Babault, 2019). It can be said that such a mechanism is the main factor for improving force. Approximately 60% of the force that rises will be caused by physical stimulation (Eng & Roberts, 2018) that affects power and maximum voluntary contractions. The mechanism also affects the improvement of maximum power during the kayak paddle.

After activation, the percentages of heart rate between the 3-minute tests for all interventions were similar, which was higher than 89% of the maximum heart rate on Kayak paddles (Michael et al., 2008; Van Someren & Oliver, 2002). However, the difference in blood lactate concentration after the test that is higher may be caused by the effect of the PAPE difference method. For using PAPE, the physiological condition requires high metabolic demand, especially when using resistance training exercises that increase blood lactate concentration and remain in the body temporarily. During strength or resistance training activities, the muscles that work within a state of ischemia have an amount of time under tension (TUT) during contractions. The muscles need to use high metabolic demand for the performed activities, especially relying upon using adenosine triphosphate (ATP), which is a source of energy for muscle contractions (Barclay, 2017) and anaerobic energy consumption in the muscles. The energy systems mentioned above cause an increase in blood lactate (Wirtz et al., 2014). This corresponds to the maximum effort of the all-out method by using a kayak paddle, which uses anaerobic energy systems as a source of energy and momentarily affects the increase of blood lactate (Bishop et al., 2001). Thus, blood lactate concentration remains in the muscles (Sang-Yong et al., 2018)until after testing for several minutes. The increase or decrease of the level of blood lactate concentration depends on the external load activities applied to the PAPE method and may affect the lactate content after the test.

Conclusions

These studies indicate that the use of post-activation performance enhancement (PAPE) such as the Resistance activation method or Maximum speed paddle effort in a short time for the warm-up strategies improves the maximum power of the kayak paddle. The high level of blood lactate concentration after preconditioning to the end of testing remains for several minutes. The resistance activation or maximum speed paddle may not be indicative of the effect associated with a decrease in related performance. However, it seems that resistance activities involving a mechanism within muscles indicate that it may cause fatigue within the muscles and tends to lower other performance. Using the maximum speed paddle method to improve the maximum power in paddling is also a way to reduce the complicating factors that affect the degradation of other performance factors better than the resistance activation method. Thus, the application of the preconditioning method depends on the goals and methods of training by coaches and trainers. Studies are needed to determine fatigue within the muscles after resistance activities, including studies on the mechanisms involved in PAPE and other parameters in the future.

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Conflicts of interest ***The authors declared no have conflict of interest publications of this paper.***

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